BRIEFING MATERIALS FOR GRAESSER'S ONR CONTRACT

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"Questioning mechanisms during complex learning" (N00014-90-J-1492), January, 1990 to January, 1992.

"Questioning Mechanisms during Tutoring, Conversation, and Human-Computer Interaction" (N00014-92-J-1826), June, 1992 to June, 1993.

The research in these two grants investigate the psychological mechanisms that underlie human question asking and answering during comprehension, conversation, and complex learning. Questioning mechanisms are fundamental components of human cognition and must be integrated in contemporary models of complex learning, curiousity, creativity, conversation, and intelligence. A scientific understanding of human question asking and answering also provides critical insights on how to design dialogue facilities in intelligent tutoring systems, expert systems, and human-computer interfaces.

The final report on the first grant was prepared in March, 1992 (Report Number R&T 4422548). Research on the second grant is currently being conducted.

Questioning during Tutoring. The primary studies in both contracts investigated question asking and answering during tutoring. We collected and analyzed the transcripts of 83 tutoring sessions on research methods (college students) and 22 tutoring sessions on basic algebra (7th graders). We estimated that student questions were approximately 100 times as frequent in a tutoring session as a typical classroom setting, as depicted in Figure 1. This in part might explain why learning is substantially better in tutoring than classroom settings (with effect sizes of .40 to 1.00 standard deviation).

We analyzed the knowledge states, strategies, and interaction patterns of students and tutors during questioning. The questions were classified on several dimensions: degree of specification, content of information requested, and the psychological mechanism that generated a question. These dimensions and categories were weakly correlated with the students' depth of understanding the material. We found that students to some extent took an active role in self-regulating their knowledge by identifying their knowledge deficits and asking questions that repair such deficits. However, students need substantial training in improving their question asking skills. There is ample evidence in the literature that the comprehension and learning of technical material can substantially improve once students have acquired the skill of asking and seeking answers to good questions.

Most of the students' answers to deep questions asked by the tutors (e.g., why, why-not, how, what-if) were poor in quality. As a consequence, the tutor helped answer these questions in the form of a collaborative process that took several conversational turns; the tutors ended up contributing more information to the answers than did the students. We analyzed the structure of these interactions, the feedback supplied by the tutors, and the cognitive strategies that generated answers to the questions. One of the noteworthy outcomes was that the tutors'

feedback (positive, negative, versus neutral) was not correlated with the quality of the students' answers, as depicted in Figure 2. Tutors perhaps gloss over poor student answers in an effort to maintain a polite conversational style or to minimize the possibility of negative feedback discouraging further output from the student. There was frequently a breakdown in the common ground between student and tutor; this in part was because the tutor erroneously believed the student had mastered the material that has been covered in the tutoring session (which is a pervasive conversational assumption). Tutors need to be trained on pedagogical strategies that penetrate the barrier of "normal, polite conversation".

Learning with a Point and Query Interface. We designed a human-computer interface that facilitates the speed and quality of questioning, called the "Point and Query" (P&Q) interface. The student points to a word or picture element on the computer screen and then to a question about that element from a menu of relevant questions. The set of relevant questions and the answers to the questions is based on a psychological model of questioning called QUEST. In a series of studies, students learned about woodwind instruments entirely by asking questions and comprehending answers (see Figure 3).

The frequency of student questions on the P&Q software was approximately 800 times the frequency in a classroom setting and 8 times the frequency in tutoring. There was a canonical order of asking questions. Taxonomic and definitional questions (e.g., What does X mean?, What are the properties of X?, What are the types of X?) tended to occur first and did not depend in the learners' goals. In contrast, causal questions (e.g., What causes X?, How does X affect sound?) occur later during learning, but only if the task constraints require that the learner acquire causal information. These findings are depicted in Figure 4. In that experiment, college students learned about woodwind instruments with the P&Q software in one of three conditions: Free Exploration (no goals), Assemble Band (a goal that did not encourage the acquisition of causal information), and Design Instrument (a goal that did encourage the acquisition of causal information).

Conditions that Stimulate Questions. We investigated the stimulus conditions that trigger questions when students comprehend text and when they attempt to solve mathematics problems. Questions were produced when there was a contradiction, when anomalous information was inserted, and when critical information was deleted. These results are consistent with an anomaly hypothesis (which predicts that anomalies trigger questions) and with an obstacle hypothesis (which predicts that questions occur when there are obstacles in planning, problem solving, or comprehension). The proposed model of question asking has three stages: (1) the detection of an anomaly or obstacle, (2) the articulation of the problem in the form of a question, and (3) social editing (which considers the costs of asking the question in a social setting). Each of these stages presents a potential barrier to asking a question.

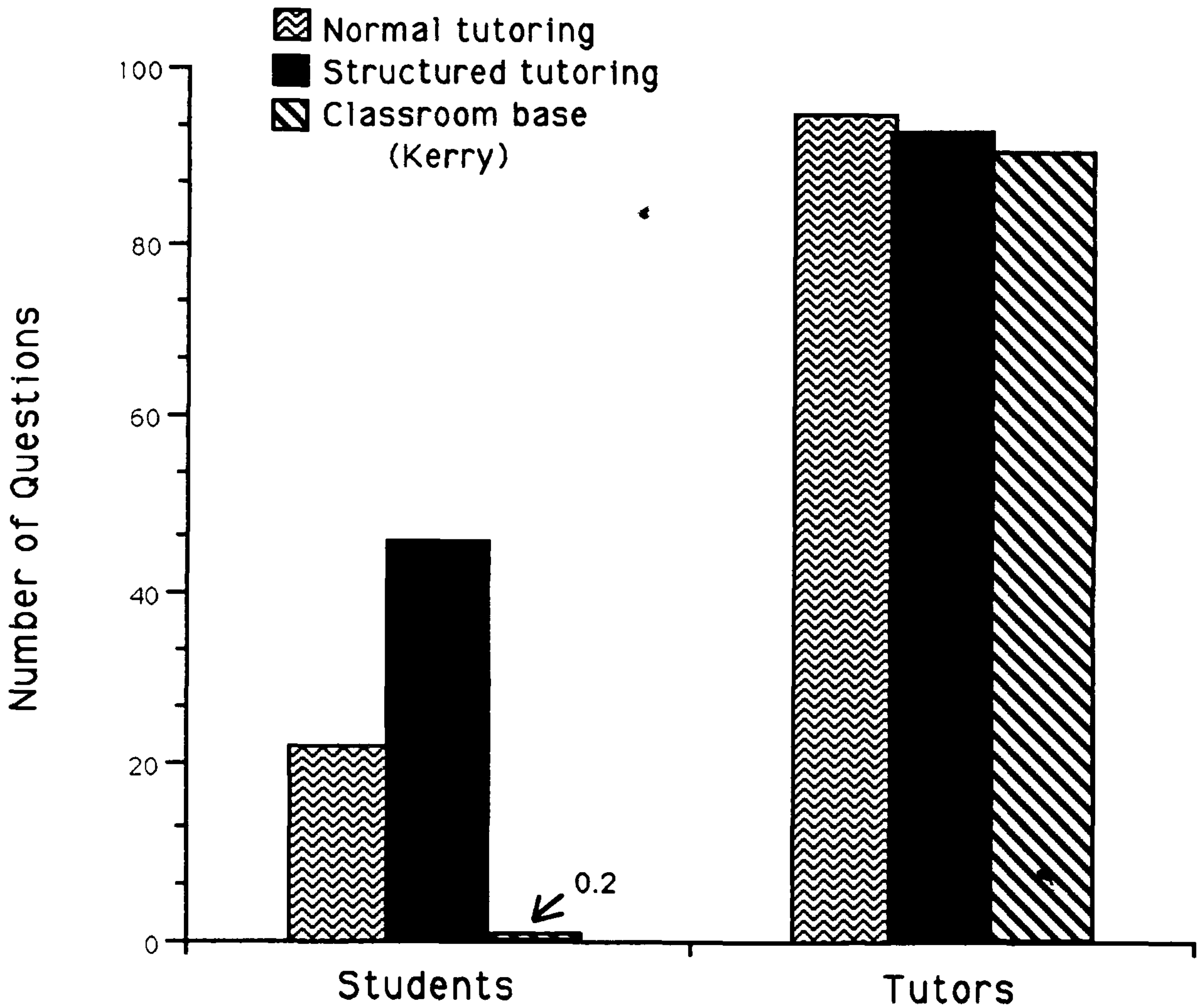
A-1

Predicting Speech Act Categories. Researchers have identified different categories of speech acts in conversation, such as Questions (Q), Replies to questions (RQ), Assertions (A), Directives (D), Evaluations (E), verbal acknowledgements (VR), and nonverbal responses (NV). There are regularies in the sequencing of speech acts between two speakers in naturalistic dialogue. We are currently investigating the extent to which various computational models can predict the category of speech act N+1, given a stream of prior speech acts, 1 to N. Two models currently being investigated are Elman's recurrent connectionist network (see Figure 5) and a recursive transition network (see Figure 6).

An index of preaiction calculates the likelihood that a model correctly predicts the next speech act category (above the base rate likelihood that the speech act would occur randomly); the index varies from 0 to 1. The index was found to be .27 in a sample of 90 conversations between children when the connectionist model was adopted. The index was substantially affected by the conversational setting (i.e., free play, a puzzle task, versus a game of 20-questions), but not by the age of the children or their friendship status. The two prior speech acts (N-1 and N) accounted for 80% of the systematicity in the predictions so local context was critical. The recurrent network was better than a back propagation network. We are currently investigating the success of a recursive transition network and are exploring the impact of higher levels of knowledge on predicting speech act categories (e.g., whether the speakers are arguing, helping each other, or involved in another pragmatic mode).

Figure 1

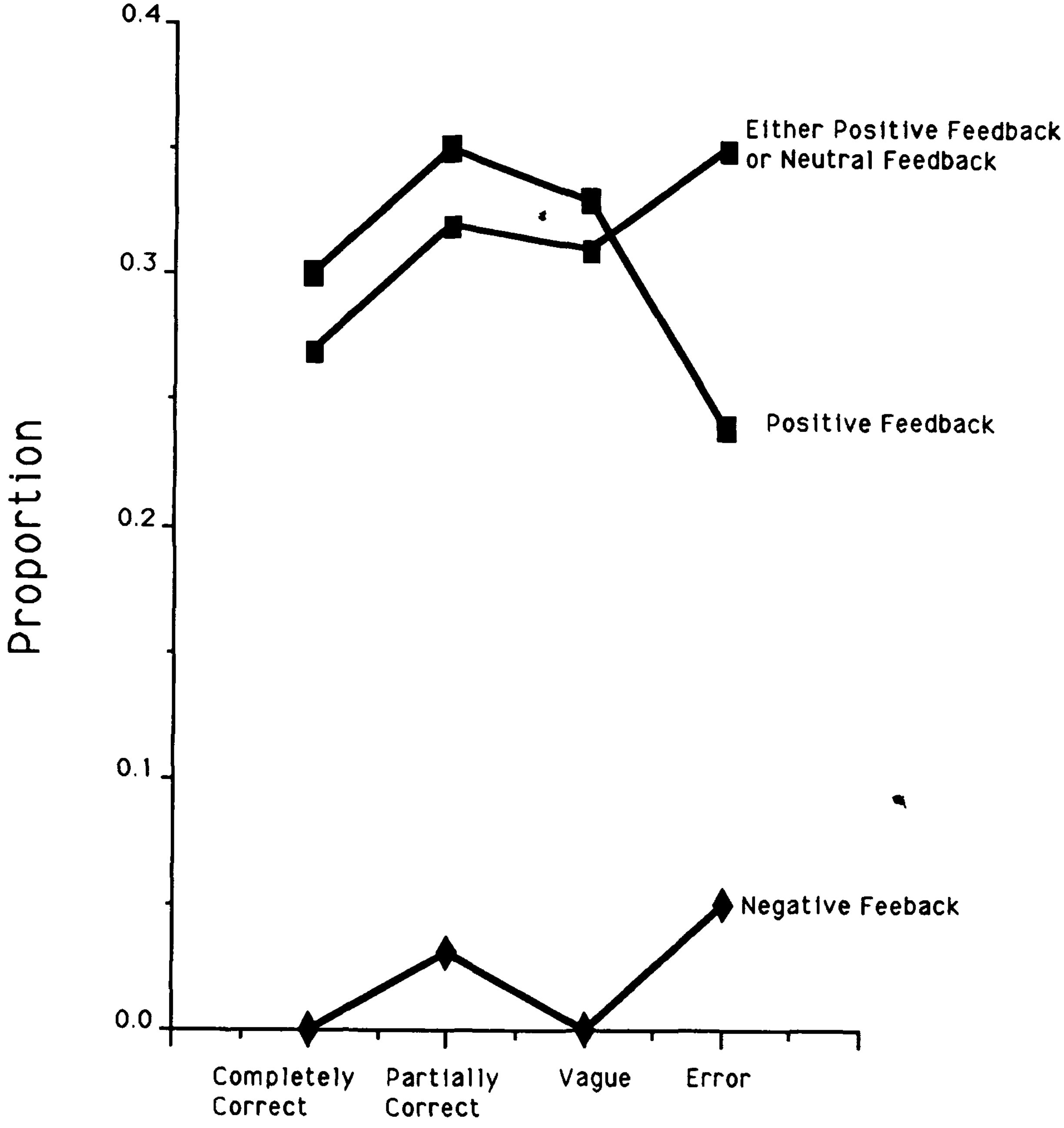
Number of Questions Per Session



Conclusion: There are more student-questions in tutoring sessions than in the classroom

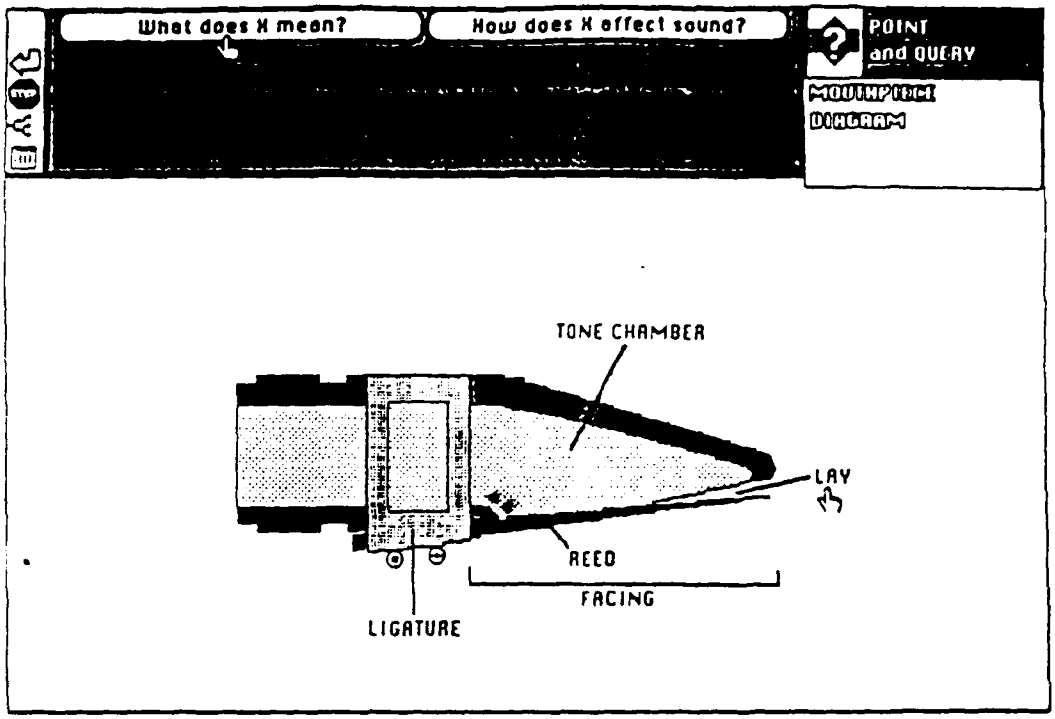
Figure 2

Feedback to Students' Answers to Tutors' Deep Questions



Quality of Students' Answer

Figure 3


What does X mean?
How does X affect sound?
POINT and QUERY
TONE CHAMBER
LAY
REED
FACING
LIGATURE

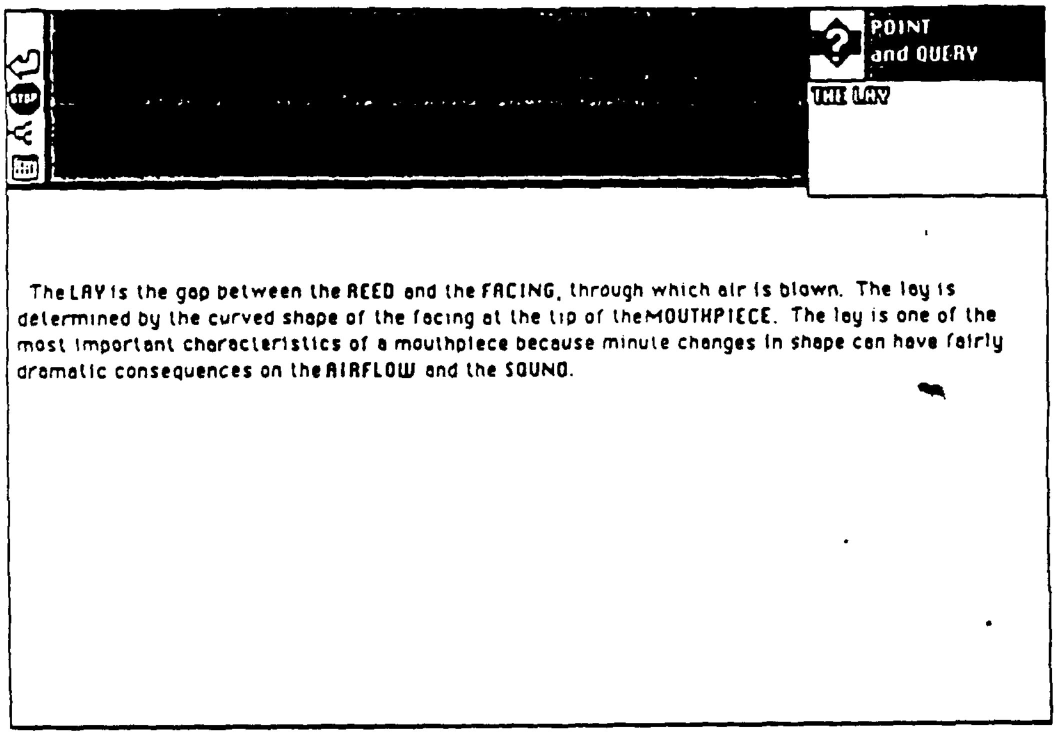
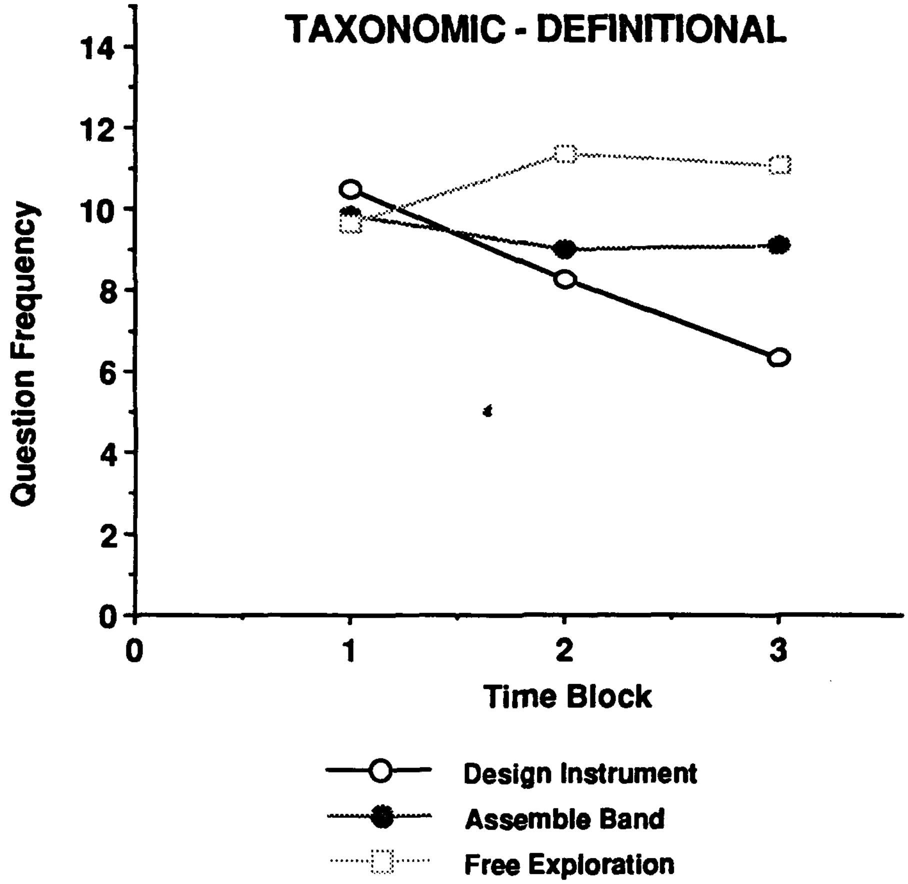
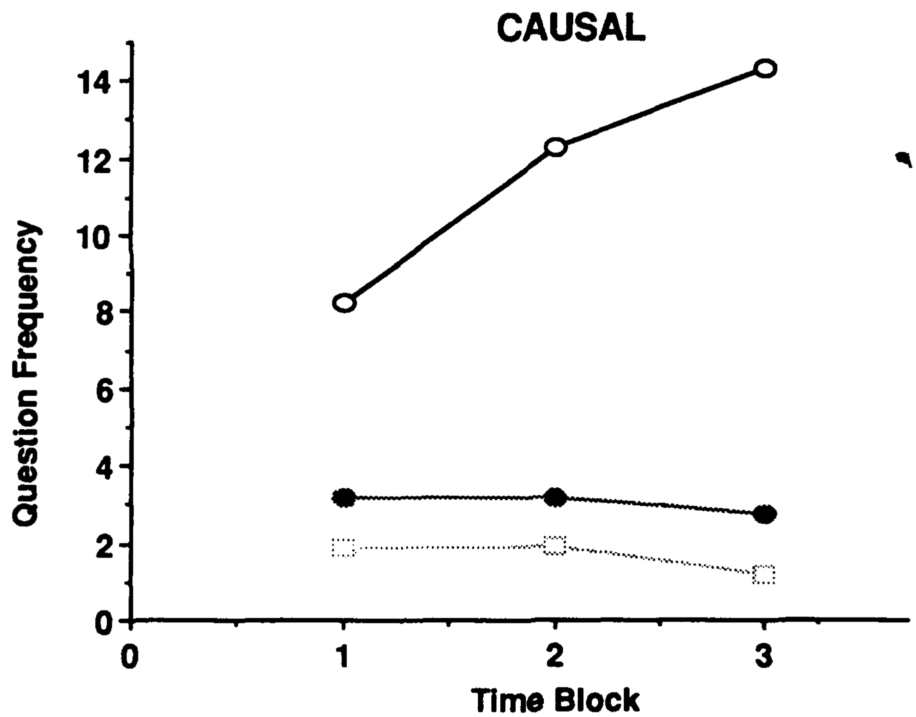

POINT and QUERY
THE LAY
The LAY is the gap between the REED and the FACING, through which air is blown. The lay is determined by the curved shape of the facing at the tip of the MOUTHPIECE. The lay is one of the most important characteristics of a mouthpiece because minute changes in shape can have fairly dramatic consequences on the AIRFLOW and the SOUND.

Figure 4



TAXONOMIC - DEFINITIONAL
Question Frequency
14
12
10
8
6
4
2
0
0
1
2
3
Time Block
Design Instrument
Assemble Band
Free Exploration



CAUSAL
Question Frequency
14
12
10
8
6
4
2
0
0
1
2
3
Time Block

Figure 5

Elman Network

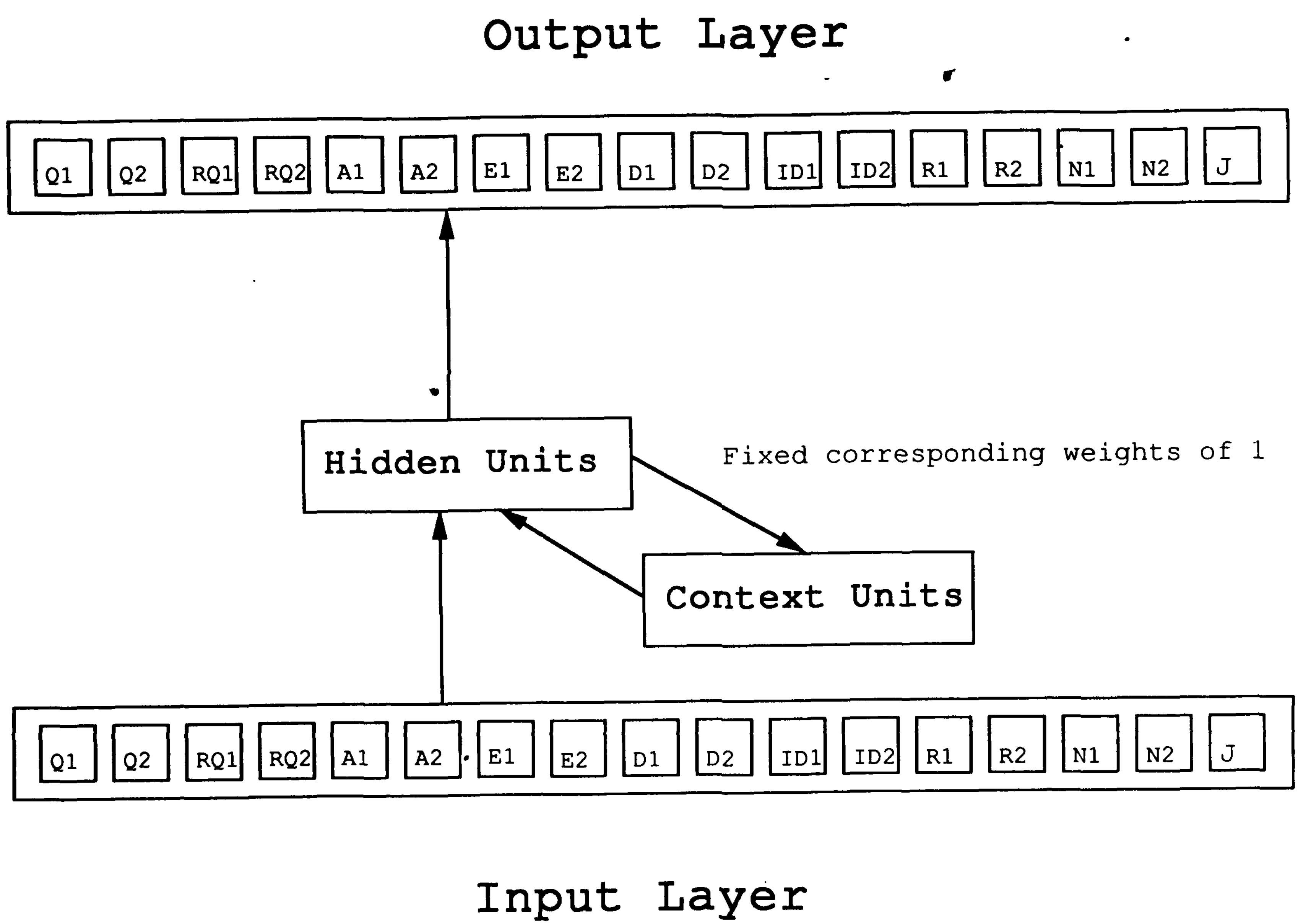


FIGURE 6: RECURSIVE TRANSITION NETWORK